

WHEAT YIELDS AND FERTILITY RESPONSE AS AFFECTED BY CLIMATE

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The affects of climate on wheat production are many and varied. It is not the purpose of this report to present an exhaustive discussion on this subject but rather to examine some of the data for Saskatchewan and point out some of the ways in which wheat production is affected by climate. The following aspects of wheat production will be considered:

- (i) production on fallow and stubble land
- (ii) production on various soil types
- (iii) production on various soil types under various fertility treatments

Yield and Climatic Data and Its Sources

In the initial phase of this project, climatic data from twelve meteorological stations was summarized. The stations chosen are shown in Fig. 1. These stations were selected because they occur throughout the broad climatic regions of the province and they had reasonably reliable long-term records. Later in the study, the records from Melfort and Scott were included.

A general picture of crop yields across the province was obtained from Statistics Canada summaries. Since 1964, Statistics Canada has collected, on a sub-crop district basis, the yields of wheat, oats, barley, flax and rapeseed. This data has been summarized as yield of these crops on fallow and on stubble. This data provides no indication of soil type, fertility levels or management levels under which yields were obtained but does give a general picture of yields.

The Sanford and Evans compilation of wheat yields by delivery points and as summarized by Dr. H.C. Moss was examined to get an indication of wheat yields on a narrow range of soil types. This data covers the period from 1931 to 1961 and for the purpose of this study only data from 1941 to 1961 were used. This was done so that these data would cover a time period for which meteorological summaries were available. These yields represent estimates in which crop yields on fallow land are not distinguished from those on stubble and there is no indication of management or fertility levels under which they

were obtained. They do, however, constitute yields from a relatively localized area of fairly uniform soil type.

The third source of yield data is from the University and Research Station trials. These were obtained from the data bank of the Soil Testing Laboratory. These yields are actual measured values of localized studies where the soil type is known and fertilizer application is documented. The level of management associated with these yields was assumed to be good.

WHY DISCUSS WHEAT?

Wheat is the crop of major economic importance in this province and hence has received much of the research attention. Furthermore, from the yield summaries compiled by Statistics Canada, it is possible to get an indication of how closely the yield of other crops was reflected in the yields of wheat. Simple linear correlations were run between all crops for all crop districts in Saskatchewan for the years 1964 to 1972 inclusive (table 1). From these comparisons, it was readily apparent that the three cereals, wheat, oats and barley behaved similarly to each other whether grown on stubble or on fallow land (minimum r value obtained between yields of cereals was 0.88 between wheat grown on fallow and barley grown on stubble. It was also quite apparent that rapeseed and flax respond to the environmental conditions quite differently than cereals and also quite differently to each other (table 1 and 2).

WHEAT YIELDS AS AFFECTED BY CLIMATE - PROVINCIAL PERSPECTIVE

In order to assess the affects of climatic variations across the province on wheat yield, regression analysis was carried out. This was done using the annual data summarized for the twelve meteorological stations and the wheat yields from the sub-crop districts in which they are located. It is realized that the yield estimates from Statistics Canada are over the relatively large area of a crop district while the climatic information has been collected at a particular point location within the sub-crop district. It was assumed that the yield estimates obtained from Statistics Canada are reasonably accurate and that the climatic data could be generalized to give an index of climatic conditions over the sub-crop district.

Stepwise multiple regression analysis was carried out using yield as the dependent variable and climatic variables as independent variables. The climatic variables included growing degree days above 42° F for the months of May, June, July and August, precipitation over the growing season (May 10 to Aug. 7) for the winter prior to seeding (November 1 to Apr. 30) for the summer prior to seeding (May 1 to Oct. 31 for fallow seeded crops and Aug. 1 to Oct. 31 for stubble seeded crops) for the winter prior to

the summer of fallow and for the fall period prior to fallow year. Included also was a measure of periods of moisture stress early in the season, in the middle of the growing season and towards the end of the season.

On a provincial basis, rainfall during the growing season was the variable selected as explaining the largest amount of the yield variation for both yields on stubble $r = .63$ and yields on fallow ($r = .55$). At step five of the regression, the multiple correlation coefficient was $r = 0.76$ for fallow and $r = 0.72$ for stubble. The other variables in the equation at step five were stress throughout the season, May and June growing degree days, the precipitation in the fall prior to harvest for the fallow seeded crop; and moisture stress in early and mid-season, May growing degree days, and precipitation in the previous fall for the stubble seeded crop.

A similar analysis was carried out for rapeseed yields and in this case the first variable to enter the regression was moisture stress early in the season for the fallow seeded crop and August growing degree days for the stubble seeded crop. By step five of the regression, growing season rainfall had not been entered as a variable. At this step, the multiple correlation coefficient was 0.77 for fallow seeded rapeseed and 0.79 for stubble seeded rapeseed.

With flax on a provincial basis growing season rainfall was an important factor in determining the yield on stubble but not on fallow.

In general, the regression model at step five was effective in explaining more than 50% ($r^2 = 0.50$) of the observed yield variation on a province-wide basis for all crops except flax grown on stubble where only 38% was explained ($r^2 = 0.38$).

A second approach taken on a provincial basis was to concentrate on crop yields as affected by moisture. The source of moisture was taken as all the precipitation occurring from the time of harvest of the previous crop up to and including precipitation during the growing season of the crop. For fallow seeded crops, this was a 24-month period while for stubble seeded crops, it was a 12-month period. The relative importance of precipitation in the various periods was determined by carrying out a multiple regression of crop yield versus the amounts of precipitation over various periods. The coefficients of the regression were then used to weight the precipitation over the time of storage and growth and the resultant weighted values were summed to give a measure

of the overall amount of moisture available to a given crop. In addition, this weighted value was divided by the growing degree days above 42° F during the growing season. This figure gives some indication of the actual amount of moisture available for crop use in relation to the possible demand as expressed by growing degree days. The wheat yields across the province versus this moisture use index are presented in figure 2. Generally, the trend illustrated shows that wheat yield is strongly related to moisture use at low values but, as moisture increases, the yield becomes less dependent and tends to plateau.

The trend lines shown on figure 2 have been fitted to the data by regression analysis. They show a striking difference of five to eight bu/acre between the yields of stubble and fallow seeded crops in the region where yields are relatively independent of moisture use. It appears likely then that this yield difference is caused by some factor other than moisture. Some of the possible reasons for this difference may be difference in seedbed preparation, date of seeding or fertility levels.

WHEAT YIELDS AND FERTILITY RESPONSE AS AFFECTED BY CLIMATE - LOCALIZED STUDIES

Data from the Agriculture Canada Research Station and the Department of Soil Science was examined with a view to comparing yields of wheat seeded on stubble and fallow land under conditions of good management where the fertility treatments were known. In order to relate these yields to climate, the trials selected were only those within ten miles of a climate station. This severely restricted the number of trials available for this comparison. The source of this data was from the data bank of the Soil Testing Laboratory which covers the period up to and including 1969.

For an initial look at this data, two levels of fertility were selected - the check yield values and the yields under general fertilizer recommendations i.e. 20 lb. P_{205} /acre on fallow and 20 lb. N and 20 lb. P_{205} /acre on stubble seeded crops.

Again, stepwise multiple regression analysis was carried out using yield as the dependent variable and climatic seeded crop, growing season rainfall was the most important variable in explaining the yield variation followed by moisture stress early in the growing season. On the fallow seeded crop, the climatic variable which explained the most of the yield variation was the precipitation in the first fall and winter of the fallow period; growing season rainfall was the second most important variable.

It is interesting to examine average yields and average yield responses to applied fertilizer on these data. The check yields of wheat seeded on stubble were 20.0 ± 6.2 bu/acre and 24.7 ± 9.7 for wheat seeded on fallow. These

yields and the differences between stubble and fallow seeded crops were similar to the average on a provincial basis. When the crop was fertilized at general recommendations, the average yield of stubble seeded crops increased only slightly to 21.2 ± 6.1 bu/acre while the yield of wheat seeded on fallow increased almost 5 bu/acre to 29.3 ± 11.0 bu/acre.

This variable fertilizer response is not surprising when it is considered that these data include trials from across the province, or widely varying climatic zones and over a variety of soil types and textures. The native fertility status of the soil also was not considered in this analysis because, for a number of the trials, it was not available.

To get some indication of the effects of soil type on the fertility response, soils of a similar texture were grouped. Figure 3 shows the yield response for wheat seeded on stubble on loam textured soils fertilized at the rate of 40 lb. N and 20 lb. P_2O_5 per acre. The results are plotted against growing season rainfall. These data are quite limited and include observations from the Swift Current area, the Scott area and the Waseca area. Within this limited amount of data, it appears that the fertility response is dependent on growing season rainfall for loam textured soils. In contrast, the fertilizer response on clay and heavy clay soils showed no real trend with increasing rainfall during the growing season. Possibly the actual spring seeding conditions or some climatic variable other than growing season rainfall is more important in influencing fertilizer response on these soils.

WHEAT YIELDS IN RELATION TO SOIL TYPE - LOCALIZED BASIS

The yield compilations of Dr. H. C. Moss from the Sanford & Evans yield estimates were examined to get some insight into the effect of soil type on wheat yields. The data selected were those delivery points situated within a common soil type and located close to one of the meteorological stations. These restrictions limited the number of soil types which were available. It was possible to select soils in the areas of Nashlyn, Kindersley, Estevan, Saskatoon and Waseca. Most of these soils were of solodized solonetz, with some solod and solonetz of loam to clay-loam texture on level to undulating topography. The wheat yields for each soil type were combined with climatic data from the adjoining weather station in a stepwise regression model.

In the regression model, the wheat yields in the Brown soil zone (Kindersley and Nashlyn) showed a strong dependence on climate, (r values ranged from 0.74 to 0.91 over 4 soil types). In the Dark Brown and Black soil zones, relationship was not as well defined (r values ranged from 0.54 to 0.78).

In the Kindersley area, it was possible to determine the climate parameters which affected the wheat yields on soils of a clay to heavy clay texture. On these soils, the first

variable brought into the regression was moisture stress throughout the growing season. Other variables included at step five of the regression were June and July growing degree days, stress late in the growing season and precipitation during the winter prior to seeding. This finding lends support to the previous observation that fertility response was not closely related to growing season rainfall on clay textured soil.

A striking feature of these analyses was that in general the most important climatic parameter affecting yields on the solodized-solonetz soils was the amount of rainfall in the summer and fall prior to seeding. A trend such as this should provide a farmer on this soil type with a firmer base on which to make management decisions.

SUMMARY

As with most discussions of this subject, the data used has been of an historical nature and has not been collected for this purpose. It is generally lacking in both scope and specificity. I do not claim, however, to have exhausted the sources of data available but I have presented some trends which are emerging from the data. These should be followed up with more data to determine whether the trends are real or merely artifacts resulting from limited data.

From these analyses, the difference between the yields of crops seeded on fallow and on stubble is quite apparent and not necessarily related to the amount of moisture available to the crop. It is of real economic importance to determine what factors do, in fact, cause this yield difference. The results presented here suggest that any study of the factors restricting yields on stubble crops should be on the basis of specific soil types.

It may be that other climatic factors such as moisture stress or periods of high temperature during critical growth periods may be involved. In this case, seeding dates for the crop in relation to the type of growing season should give some information on this. It may well be that particular soil types or particular areas will require slightly delayed or very early seeding dates to achieve the best yields with the prevailing climate.

Fertilizer response as it is affected by climate may well depend on soil type.

The overall conclusion from this study is that it is of extreme importance to bring the data bank of the Soil Testing Laboratory up to date and make it as complete as possible. When this is done, hopefully, much of the information

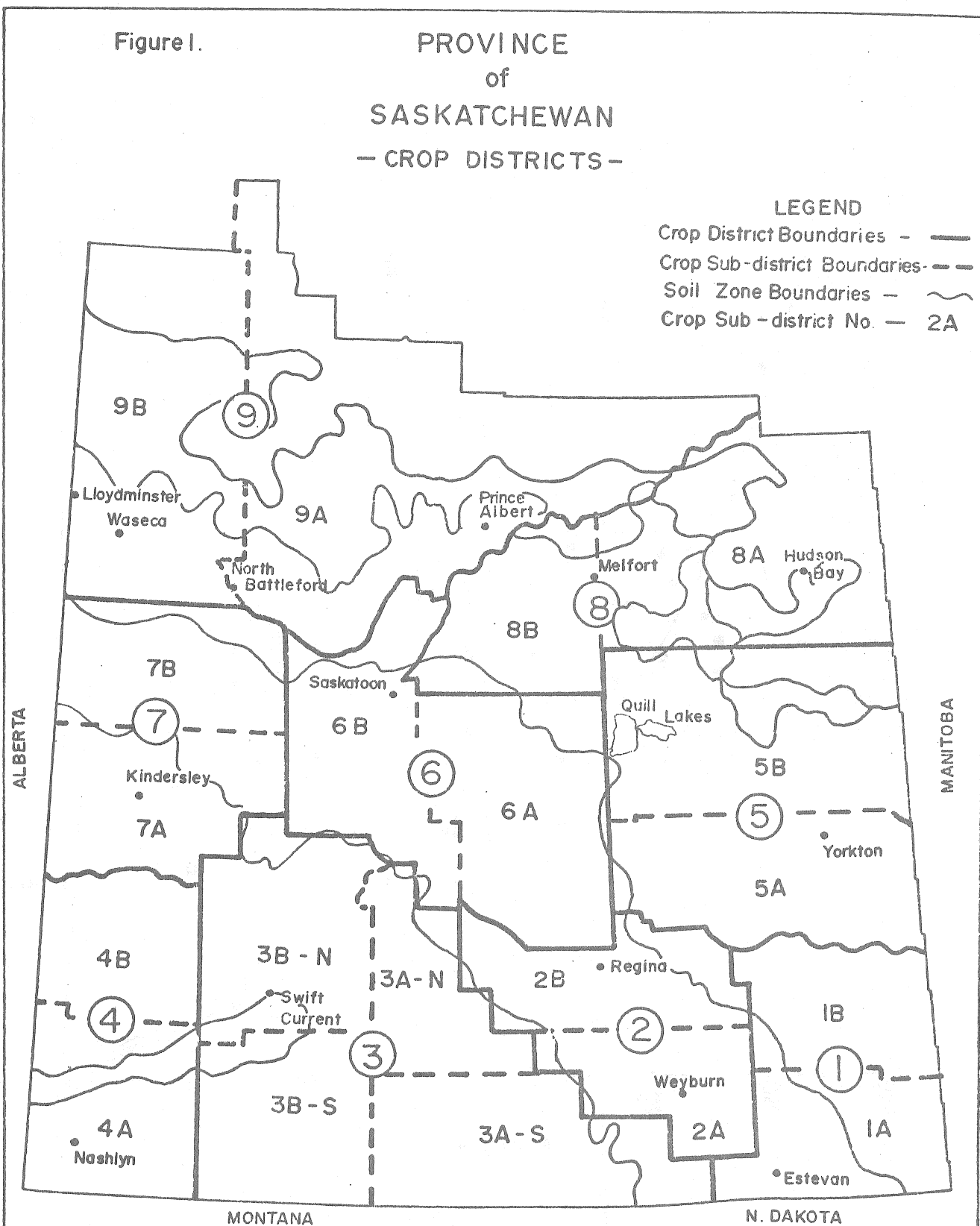
necessary to either expand and confirm some of the trends described here or reject them will be available. As far as possible, any further studies also should be related to soil type and climate - not just growing season climate, but climate throughout the full year.

TABLE 1. CORRELATION COEFFICIENTS FOR YIELDS OF VARIOUS CROPS
IN THE 9-YEAR PERIOD 1964-1972

		FALLOW				STUBBLE			
		WHEAT	OATS	BARLEY	FLAX	WHEAT	OATS	BARLEY	FLAX
F	WHEAT	1.00	0.90	0.93	0.76	0.92	0.87	0.88	0.72
A	OATS		1.00	0.95	0.79	0.90	0.95	0.91	0.75
L	BARLEY			1.00	0.80	0.91	0.92	0.94	0.77
L	FLAX				1.00	0.75	0.78	0.78	0.78
O									
W									
S	WHEAT					1.00	0.92	0.93	0.75
T	OATS						1.00	0.94	0.77
U	BARLEY							1.00	0.77
B	FLAX								1.00
B									
L									
E									

TABLE 2. CORRELATION COEFFICIENTS FOR YIELDS OF WHEAT, RAPESEED AND
FLAX FOR SASKATCHEWAN CROP DISTRICTS 5-9.

		FALLOW			STUBBLE		
		WHEAT	FLAX	RAPESEED	WHEAT	FLAX	RAPESEED
F							
A	WHEAT	1.00	0.76	0.66	0.93	0.63	0.41
L	FLAX		1.00	0.42	0.69	0.50	0.27
L	RAPESEED			1.00	0.63	0.40	0.52
O							
W							
S							
T	WHEAT				1.00	0.66	0.38
U	FLAX					1.00	0.14
B	RAPESEED						1.00
B							
L							
E							



WHEAT YIELDS ACROSS SASKATCHEWAN 1964 - 1970

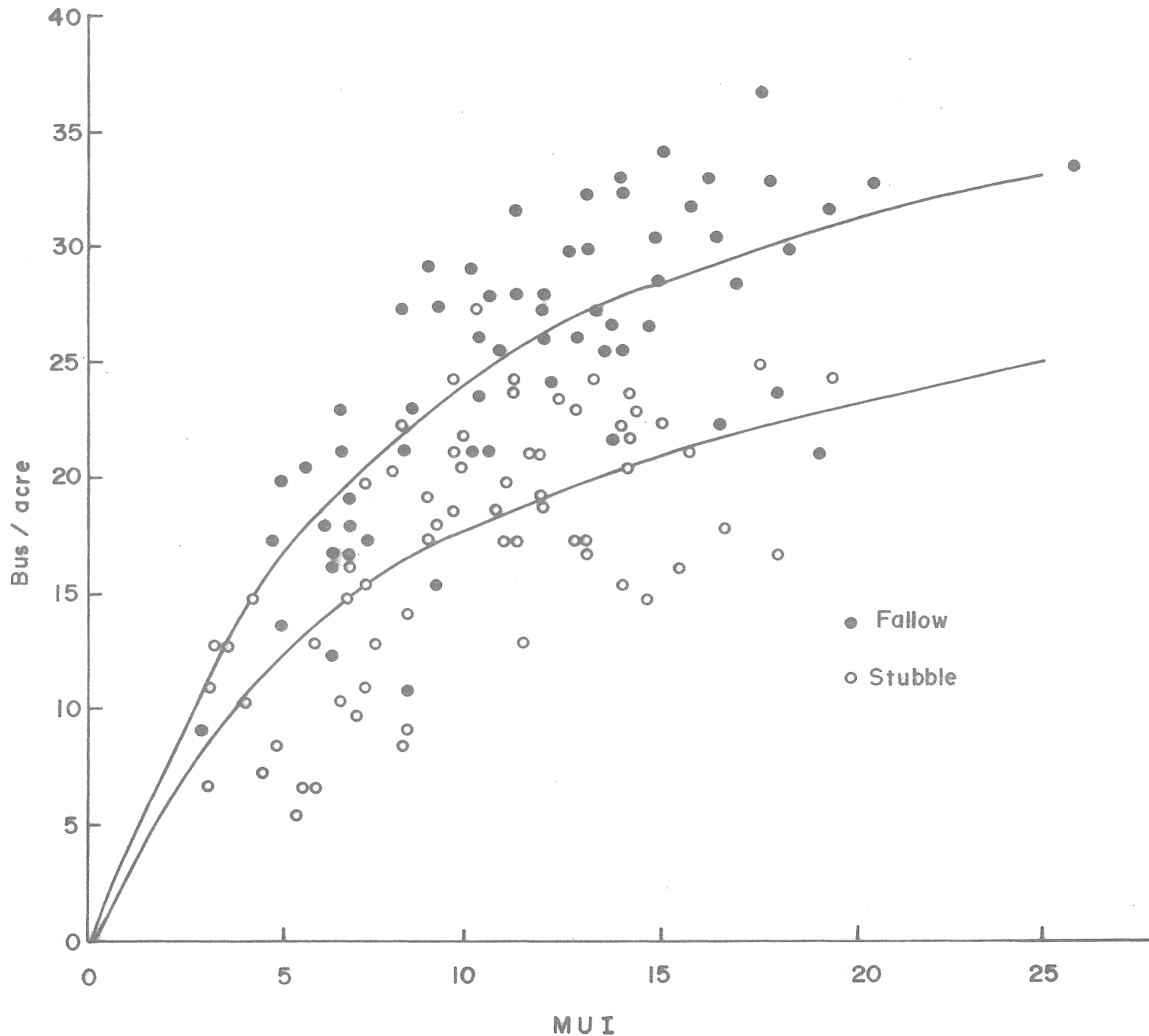


Figure 2: Relationship between wheat yields at 10 sub-crop districts across Saskatchewan and a moisture use index (MUI)

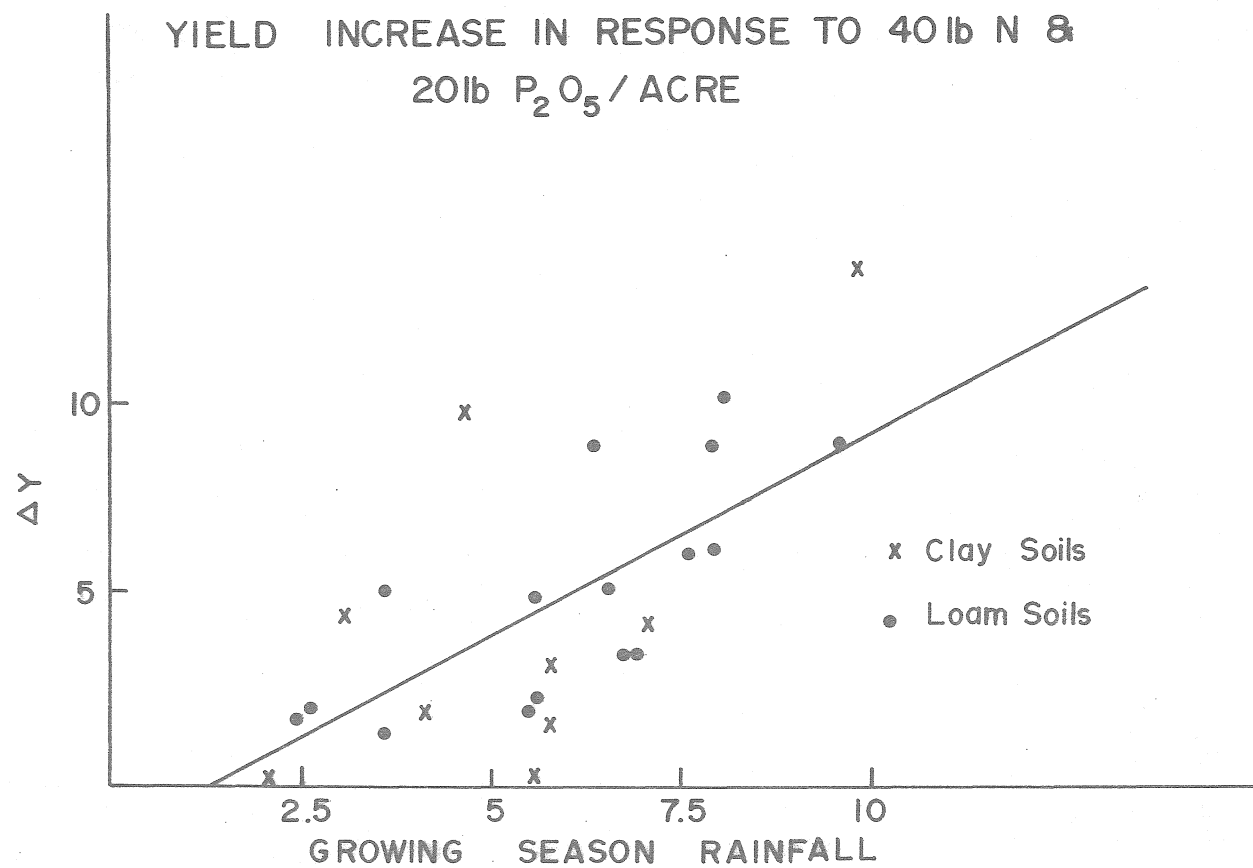


Figure 3: Yield increase of wheat on stubble land versus rainfall during the growing season.